Analysis of Techniques for Estimating Evacuation Times for Emergency Planning Zones

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ABSTRACT

Limitations of current methodologies and some alternatives are discussed that point out that evacuation time is a combination of the time required for four separate actions. These are decision, notification, preparation, and response (travel) time. Times for these actions will overlap to some degree with some people receiving notification, some preparing to leave, and others traveling. Notification and preparation times significantly affect the evacuation time and must be known before time to clear an area can be calculated accurately.

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I. INTRODUCTION

Transportation analysis and planning techniques are routinely applied to everyday types of problems such as existing peak-hour traffic congestion and future transportation system needs. Only recently has interest been focused on rare or low probability events such as natural or man-made disasters.

In reviewing the literature relative to evacuation planning in the event of a nuclear incident, it is apparent the existing knowledge developed in the field of transportation analysis and planning has generally not been used to develop evacuation estimates around nuclear facilities. This report will briefly look at the state of the art of evacuation planning principally from the point of view of transportation engineering techniques in concert with other emergency response planning procedures.

The steps to be followed in this paper will be to first discuss current emergency planning methodologies. In the process of discussing current methodologies, operational definitions of key terms will be developed, as it is apparent that usage of terms is not consistent. Second, existing transportation planning techniques and transportation planning models will be discussed and their applicability to nuclear evacuation planning analyzed. Third, current Nuclear Regulatory Commission evacuation planning requirements will be reviewed. Lastly, recommended procedures will be proposed for reviewing evacuation plans currently being developed by NRC licensees.

II. CURRENT EVACUATION ANALYSES

The probability of a nuclear accident, while small, is not zero (Collins, et al., 1978). Measures to improve public safety have tended to favor reductions of this probability and its consequences as opposed to planning for large scale evacuations. This approach was logical given the characteristics of the design basis loss-of-coolant accident, but is not consistent with the current goal of protecting the public in the event of a core melt accident. Moreover, most existing reactor site evacuation models appear to be overly abstract models of the evacuation problem that cannot be considered adequate under NRC's revised requirements for evacuation planning. It is appropriate, first, to digress briefly and define some key terms.

The term "evacuation time" is used by different analysts to represent different components of the time between detection of an incident and the completion of an evacuation. It is essential to use other terms to describe the components of evacuation time. Our definition of "evacuation time" will represent the interval of time from the detection of an incident which ultimately requires evacuation to the end of the period required for individuals to physically move out of an area.

The components of evacuation time are as follows:

decision time   = The time elapsed from detection of an incident until a decision is made by competent authority to order an evacuation.

notification time = The time required to get the evacuation

notification to all individuals in the specified

area.

preparation time = The time required for individuals to prepare to

evacuate the specified area.

response time = The time required for individuals to physically

move out of a specified area.

For each individual evacuee, evacuation time is the sum of all the

component times. In actuality, there may be different notification,

preparation, and response times for each individual evacuee. Thus, in an

area designated for evacuation there is a distribution of times for each

of the components just defined rather than a single point in time. When

viewed from the perspective of the agency responsible for the evacuation,

this means that certain phases of the evacuation will overlap. That is,

at any point in time, some residents may be in the process of being

notified, others preparing to evacuate and still others in the process of

leaving. Note that these components do not include confirmation time in

the overall estimate of evacuation time. Confirmation time--the period

during which it is verified that the affected population has

departed--may occur concurrently with or subsequent to evacuation.

It is important to understand that estimates of the length of the

time period from the decision to evacuate through clearance of the

evacuation zone is significantly affected by the time required for both

notification and preparation. That is to say, the length of time that it

takes to clear the area cannot be calculated with any degree of certainty

without knowing how long it takes to notify the populace of an impending evacuation, and how long each person will consume in preparation. Unfortunately, little research has been done that addresses either of these two problems. However, some general assumptions can be made with respect to preparation time for the general population. Notification systems will be subject to design criteria for maximum elapsed time.

Factors affecting the length of time that would be involved in the response phase are better understood. Response time is a function of the volume of traffic and the capacity of the roadway. As the ratio of traffic volume to roadway capacity increases, speed decreases. If the traffic volume exceeds the roadway capacity, the speed can and does approach zero (stop and go traffic). The problem with excess demand is that capacity is less than the maximum possible and speeds are lower than those possible at maximum capacity.

It is, therefore, necessary to know the time distribution of evacuation demand so that the time distribution of traffic volumes can be calculated. The traffic volumes can then be compared to roadway capacities, and then the response time can be calculated. If, however, traffic volume exceeds roadway capacity on one or more roadway segments, traffic management or demand management techniques are necessary to avoid the problems of oversaturation (reduced capacity and speed). In summary, evacuation times are a function of a complex interaction between evacuation demand and roadway capacity. Alternative methodologies that can be used to estimate evacuation times can be classified as either empirically based or theoretically based models. In reality, each can

have aspects of the other. However, the methodologies examined appeared to lean heavily toward one of the two approaches.

Hans and Sell (1974) collected data from 54 incidents thought to have occurred with short warning times and to closely approximate nuclear reactor evacuation conditions. The events which were selected covered a wide range of population sizes, disaster agents, number of people evacuated, meteorological conditions, times of day, and roadway conditions.

No correlation was found in their sample between evacuation time and several other factors. The factors for which no correlation was found included time of day, weather conditions, and road conditions. This result is quite surprising since experience suggests that some of the factors analyzed do affect response time. It is quite possible that the aggregated nature of the data and other limitations of their sample are the reasons other correlations were not found.

Hans and Sell did find an inverse relationship between population density and evacuation time as defined as the sum of notification time plus preparation time plus response time. They postulated three reasons that might explain their finding:

1. Notification time increases in low density areas.

2. Preparation time increases in low density areas.

3. Response time decreases in high density areas.

As we stated previously, these three components of evacuation time must be explicitly considered in the analysis process to identify critical relationships. The evacuation data examined by Hans and Sell (1974)

could not be broken down in a manner suitable for testing any of these three individual postulates. Nor did they test these hypotheses by examining other bodies of data. This is particularly significant in regard to the advent of rapid notification systems and public education efforts. Both rapid notification and public education may reduce warning time, preparation time and response time in emergency planning zones to the extent that conditions during an actual event may differ markedly from the situations analyzed by Hans and Sell. These factors would further reduce the applicability of the correlation between population density and evacuation time.

One final note of caution concerning these data is due to the size of the areas evacuated. Although Hans and Sell (1974) collected data on 54 incidents, they only used 19 in their regression analysis. The area evacuated in these 19 incidents had a mean area of 27.5 square miles. This mean is affected greatly by two data points having areas of 100 and 336 square miles. The median area is 3.1 square miles and the average without the two incidents previously mentioned is 5.1 square miles. The nuclear emergency planning zone is typically 314 square miles and actual evacuations may range from a few square miles to over 100 square miles in any emergency in which evacuation is the protective measure of choice. Hence, the data base of Hans and Sell appears to be weighted toward smaller evacuation areas than may be the case for evacuations during emergencies at nuclear reactors.

In conclusion, it appears that there are several problems in applying the available empirical data to site-specific studies. The data do not

separate warning, preparation, and response time, yet it is postulated by Hans and Sell (1974) that these factors may explain the obtained relationship. There is some question as to how representative data for small evacuation areas are to large scale evacuation. In addition the rapid notification time envisaged for nuclear planning zones may lead to different conclusions for the relationship of evacuation time and population density. It is therefore quite possible that the correlation reported by Hans and Sell (1974) may, in fact, indicate a relationship between population density and notification, preparation, or response time, that may not be directly applicable for estimation of specific evacuation times for large area with rapid notification systems.

Strenge, Soldat, and Watson (1978) and Houston (1976) describe efforts to develop theoretically based evacuation models. Since both of these models use the inverse relation reported by Hans and Sell, they are subject to the limitations discussed above. It is noteworthy that Strenge, et al., (1978) indicate that specific site characteristics were not considered and suggest that improvements are needed for application to site-specific analyses. They specifically note the necessity for considering highway networks.

Although these models may be appropriate for other purposes, they clearly need modification for use on a site-specific basis. Rather than look further to these models for means of improving the process of estimating evacuation times, we shall turn our attention to some transportation planning techniques that have not been previously used to evaluate emergency evacuation problems.

III. <u>ALTERNATIVE METHODOLOGIES</u>

Transportation professionals have developed a somewhat standardized and sometimes complex transportation planning process. The complexity is partly due (Grecco, et al., 1976) to the use of mathematical models which can result in misplaced emphasis on the details of calculational algorithms. Overzealous attention to mathematical accuracy may supplant a more fundamental analysis of the accuracy of the basic asssumptions about human behavior. Furthermore, the quantity of data that is required can be substantial. Nevertheless, much has been learned from the use of mathematical techniques in traditional transportation planning. The extensive experience which has been gained has also resulted in many simplified techniques. The following discussion will briefly describe those aspects of the standardized transportation planning process that are applicable to evacuation planning for nuclear power plants. The standardized transportation planning process for travel estimation has four steps: (1) trip generation, (2) trip distribution, (3) mode split, and (4) traffic assignment. Each of these steps will be discussed in turn.

In the 1950's, transportation planners began quantifying distinct travel relationships (U.S. DOT, 1967). Urban traffic patterns were found to be a function of:

1. The pattern of land use in an area, including the location and intensity of use;

2. the various social and economic characteristics of the population of the area (e.g., auto ownership, income, and household size); and

3.   the type and extent of transportation facilities in an area.
These relationships are utilized in the first step of the transportation
planning process, trip generation.

Trip generation analysis is usually stratified into two components:

1.   trip generation at the household level; and

2.   trip generation at the non-residential level.

This stratification is also appropriate for nuclear evacuation planning.
The nuclear evacuation planning process, however, is greatly simplified
since only one type of trip, evacuation, needs to be estimated. The
stratification is particularly significant since daytime and nighttime
populations are likely to vary significantly.

Normally, time-of-day characteristics are considered after trip
distribution or traffic assignment. In the nuclear evacuation planning
process, it may be simpler and more accurate to generate trips for
different times of the day directly.

Trip distribution, the second step in the standard transportation
process, is the procedure of linking trip origins with trip
destinations. Trip distribution is normally a complex part of the
transportation planning process. The process is especially difficult in
projecting origins and destinations for future conditions. In nuclear
evacuation planning, this step would be significantly simplified in that
all traffic is destined.outside the emergency planning zone, the final
destination is unimportant if it is assumed that evacuees take the most
direct route out of the risk area. Trip distribution then becomes an
essentially trivial process.

Mode split, the third step in the process, is the procedure of determining the portion of trips made by other than private auto. The percentage of trips to be made by evacuees in private cars is likely to be very high. The approach that could be used for nuclear evacuation planning would be to consider nonauto trips separately. This is the procedure used in small urban areas with limited public transportation.

Prior to the last step in the process, traffic assignment, it is necessary to transform person-trips (the normal output of trip generation, trip distribution, and mode split) into vehicle-trips (the normal input into traffic assignment). The parameter used in the transformation is automobile occupancy. Unfortunately, the data base for automobile occupancy during evacuations is limited. Nevertheless, the limited data plus reasonable assumptions based on similar trip purposes should result in a satisfactory estimate of automobile occupancy. One could, for example, estimate the average occupancy of private vehicles to be the ratio of the non-institutionalized population divided by the total number of automobiles in a given area. This is the most conservative approach as it results in the largest estimate of the number of automobiles. Alternatively, it might be assumed that only one vehicle per household would be used. This assumption results in an estimate of the fewest automobiles being evacuated. One significant advantage of the standard transportation planning process is its modularity. As better data or techniques are developed, they can be used in the process without having to redo the overall methodology.

Traffic assignment (Comsis, 1973) is the process used to aid in development of loadings on a network of transportation facilities. The result of the assignment process is an estimate of user volumes on each segment of a transportation network. Traffic assignment is used to simulate current traffic volumes or to forecast future volumes on a transportation system.

Input to the traditional traffic assignment process involves:

1. Network geometry - This may be viewed as a map of the network to be studied.

2. Network parameters - Typically the minimum travel time is the basis used to select routings through the network.

The output of the process is traffic volume on each segment of the transportation network.

Although traffic volumes can be assigned in a relatively straightforward (although not trivial) process, travel time on a network link is actually a function of the volume assigned and the link capacity. The basic relationship is that as traffic flow increases, traffic speed decreases. If volumes exceed capacity, speeds can be reduced to near zero for short periods. This unstable condition, called forced flow, results in reduced flow rates as well as reduced speed. After the initial assignment is completed, volumes assigned on some links may result in longer travel times than initially assumed. The increased travel time on certain links may then make alternate routes the minimum time path. An iterative process is used to balance the mathematical model of the system. This process would be especially useful in nuclear

evacuation planning, as it would identify potential bottlenecks and alternative routings.

IV. CURRENT REQUIREMENTS

The Nuclear Regulatory Commission has extensive requirements for nuclear reactor site planning. Recently (Grimes, 1979), more detailed estimates of the notification time and the sum of preparation time and response time have been requested for specific sectors and segments of the emergency planning zones surrounding nuclear power facilities. The following will briefly analyze those requirements.

The present request reflects the fact that evacuation time includes several components including notification time, implementation time, and confirmation time. Because implementation time includes preparation time and response (transportation) time, the process is essentially identical to the model developed earlier in this report.

Two general methods of estimating the time to implement evacuation (after notification) are mentioned, although no standard method is currently recommended. One method is to use previous local experience with chemical spills or floods. This approach is essentially equivalent to the approach used by Hans and Sell (1974), which was discussed earlier. It therefore has the same inherent limitations, namely the failure to separate the components of evacuation time and the differences in sizes of areas evaluated. It is doubtful that either of these problems can be overcome. It also seems unlikely that new data could be collected to overcome the limitations because future notification times

and preparation times may be expected to differ markedly from previous experiences.

The second general method discussed in NRC's recent request is based on population density, local geography, and roadway capacities. This approach is a step toward the transportation planning process described in the previous section. It begins to recognize the demand capacity relationship of specific land use and roadway networks. The process, although an improvement over the other approach, is not without limitations. The analysis is subject to error whenever the scope is limited to estimates of the total demand and capacity of perceived critical links.

Unless the analysis is performed systematically for all transportation links, the wrong roadways may be selected as critical links. A specific example will illustrate. It was generally assumed by planners that the Interstate 45 bridge to Galveston Island in Texas was the critical link for hurricane evacuation. Estimates were made of evacuation time based on this assumption. A more detailed study (Urbanik, 1978) concluded that the bridge was not the critical link. The city's street system was incapable of supplying sufficient vehicles to reach the bridge's capacity.

The NRC's request seems to place emphsis on zone configurations based on various segments and sectors of a circle. More emphasis should be allowed to other considerations (e.g., political, transportation, or geographical boundaries) and additional flexibility should be allowed to accommodate such considerations. The goal is to present time estimates in a format that will aid a realistic assessment of the options.

In the standard transportation planning process, zones are generally developed in accordance with the objectives of the analysis. Zones are therefore related principally to the transportation network. Secondary considerations concern:

1. census tract boundaries,

2. geographic boundaries,

3. political boundaries, and

4. other input data requirements.

Ideally, the zone system would include at least one zone for each land area bounded by the roadway network. These zones would be subdivided if necessary to provide zone boundaries at a finer level of detail. For nuclear evacuation planning, the network configuration approach to zones would be appropriate for an additional reason. Evacuees can easily relate to areas bounded by major roadways. However, other zone systems are feasible, and the optimum selection may depend upon the characteristics of a planning area.

It appears that the reporting format (approximately 90° quadrants) suggested by the NRC is reasonable although two evacuation times should be reported for each zone. One time should be for evacuation of that zone only and the second time would be for simultaneous evacuation of all contiguous zones. The latter estimate would reflect the fact that a single sector may be evacuated faster using adjacent sector roadways. This dual analysis would not require significantly more effort than a single analysis.

The following discussion addresses the six items specified by NRC (Grimes, 1979) as required information. Separate estimates for normal and adverse weather conditions seem appropriate. However, the potential time-of-day variation of traffic assignments (e.g., day versus night) also needs to be considered.

Separate consideration of special facilities is important because they involve distinctly different processes than those governing the evacuation of the general public. Since the evacuation of special facilities would typically be accomplished concurrently with a general evacuation, evacuation time estimates for special facilities should clearly reflect any impacts of the general evacuation. Evacuation times for many large special facilities (e.g., hospitals) may be as long or longer than the evacuation time for the general public. Thus, separate estimates for special facilities and for the general public provide a clearer understanding of the potential health impact to each group. Indeed, analysis may indicate that sheltering, not evacuation, is the preferred protective action for some special facilities. In general, many different types of traffic generators such as factories, universities, or military bases have a seasonal or time-of-day variation that may require special consideration.

Confirmation time is not considered in this report primarily because it is not a factor in deciding whether an evacuation is feasible or advisable. Moreover, many emergency response plans call for confirmation to be conducted in the course of security patrols of evacuated areas. Thus, confirmation and response can also be conducted concurrently.

Confirmation may proceed in a zone proximal to a power plant while evacuation is being conducted in a more distant zone.

Notification and warning time have been discussed in a separate report by Lindell, et al. (1979). Notification times will be affected by a federal requirement for notification systems for nuclear emergency planning zones and will not be discussed further in this report. Sheltering is a protective action that could be taken either instead of or in addition to evacuation. However the relationship between these two modes of protective action is a special consideration not discussed here.

In conclusion, it appears that compliance with the NRC's current request could result in acceptable evacuation time estimates, but inadequate analyses might also satisfy the minimum criteria of the request. Such inadequacies could result from using undesirable methods of analysis. It is unlikely that such a minimal effort or an undesirable approach will produce a reasonably accurate assessment of evacuation time.

V. SUMMARY

The preceding sections have indicated the limitations of current methodologies and provided a discussion of some alternatives that meet NRC's needs. The alternatives represent a wide range of techniques that require some adaptation to the problems that would be posed by evacuations of areas surrounding nuclear power plants.

Alternatives adapted from existing transportation planning techniques can provide reasonable estimates of evacuation response time for specific nuclear power plant sites. These techniques would be expected to be

understandable to the public since they relate population (including location, density, and socioeconomic characteristics) to the type and extent of transportation facilities in an area. The recommended techniques constitute a significant improvement over existing techniques which have been shown to be generally inappropriate for developing or analyzing site-specific nuclear evacuation plans.

VII. RECOMMENDATIONS

Ideally, a research program should be undertaken to specify some of the parameters of nuclear power plant evacuation planning, then a model plan should be developed and tested on a limited number of sites prior to specifying the planning requirements. Because of the accelerated rate at which emergency response plans are being upgraded, such an approach is not feasible. Recommendations can be made concerning the information that should be required and the criteria that should be used in evaluating estimates of evacuation times.

Appendix A presents an example estimate of evacuation times that indicates what should be included in an analysis. This appendix could be substituted for the "Required Information" section of Appendix 4 of NUREG-0654 (Grimes and Ryan, 1980). Appendix B contains a proposed framework by which the various plans can be compared and evaluated.

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APPENDIX A

EXAMPLE EVACUATION TIMES ESTIMATE

The following is an example of what should be included in an evacuation times assessment study and how it might be presented. The example includes a complete outline of material to be covered, but only a few typical tables and explanations are provided.

1. INTRODUCTION

This section of the report should make the reader aware of the general location of the facility, and generally discuss how the analysis was done.

A. Site Location

A vicinity sketch showing where the plant is located should be provided along with a detailed map of the emergency planning zone. The map should be legible and should identify transportation networks, population distributions, topographical features and political boundaries in such a way that the unfamiliar reader can obtain a feel for the nature of the area. The map should also show the major compass directions. If the sectors are not selected according to major compass headings, the rationale used for selecting the sectors and an outline of the sector boundaries would be helpful. (This is not intended to discourage selections according to geographical, political or transportation network boundaries. Indeed, sectors based upon these criteria will generally be more useful to local authorities and the general public.)

B. General Assumptions

All assumptions used in the analysis should be provided. The
assumptions would include such things as automobile occupancy factors,
method of determining roadway capacities, and method of estimating
populations.

C. Methodology

A description of the method of analyzing the evacuation times should
be provided. If computer models are used, a general description of the
algorithm should be provided along with a source for obtaining further
information or documentation.

II. DEMAND ESTIMATION

The objective of this section is to provide an estimate of the number
of vehicles to be evacuated. It is suggested that three potential
population segments be considered: permanent residents, transients, and
special facility residents. Permanent residents include all people
having a residence in the area, but not in institutions. Transients
would include tourists, employees not residing in the area, or other
groups that may visit the area. Special facility residents include those
confined to institutions such as hospitals and nursing homes.

A. Permanent Residents

The number of permanent residents could be estimated using the
U.S. Census data or other reliable data, adjusted as necessary, for
growth. This population data would then be translated into a projected

number of vehicles using an appropriate auto occupancy factor. A range of 2 to 3 persons per vehicle would probably be reasonable in most cases, however, any rational basis would be appropriate. For example, one vehicle per household might be a reasonable assumption.

B. Transient Populations

Estimates of transient populations would have to be developed using local data such as peak tourist volumes and employment data for large factories. Automobile occupancy factors would vary for different transient groups. Tourists might have automobile occupancy factors in the range of 3 to 4 while a factory would probably have a factor of less than 1.5.

C. Institutional Population

An estimate for this special population group should usually be done on an institution-by-institution basis. The means of transportation would also be highly individualized and should be described.

D. Sample Format

Figure 1 is an example of a means of summarizing population data by sector and distance from the plant. Separate totals would be provided for the three population segments. Figure 2 shows the population totals translated in the number of vehicles estimated to be used in evacuation.

III. TRAFFIC ROUTING

This section of the report would show the facilities to be used in evacuation. It would include their location, types, and capacities.
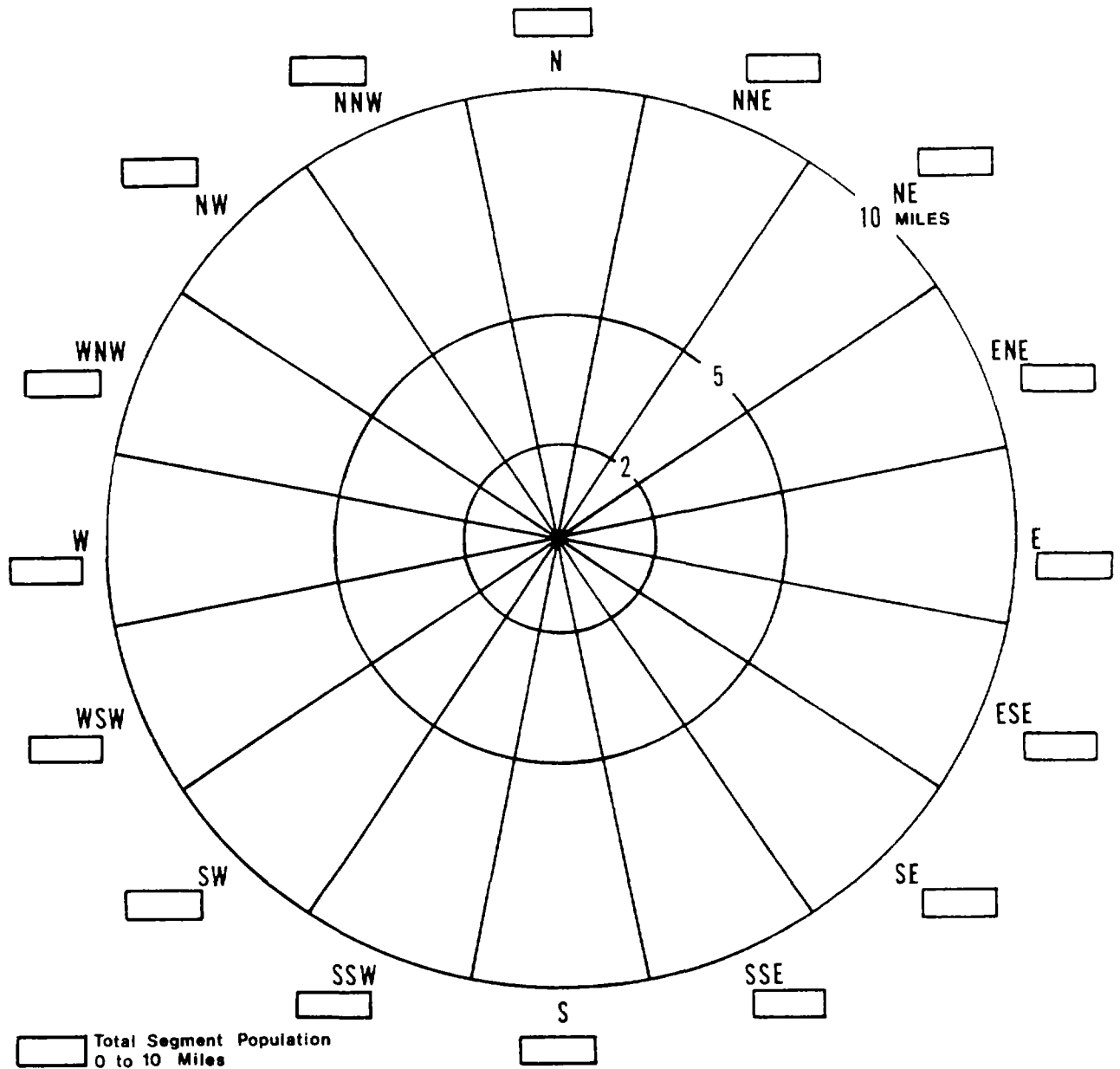
Figure 1: Example of Format for Presentating
Population Data By Sector
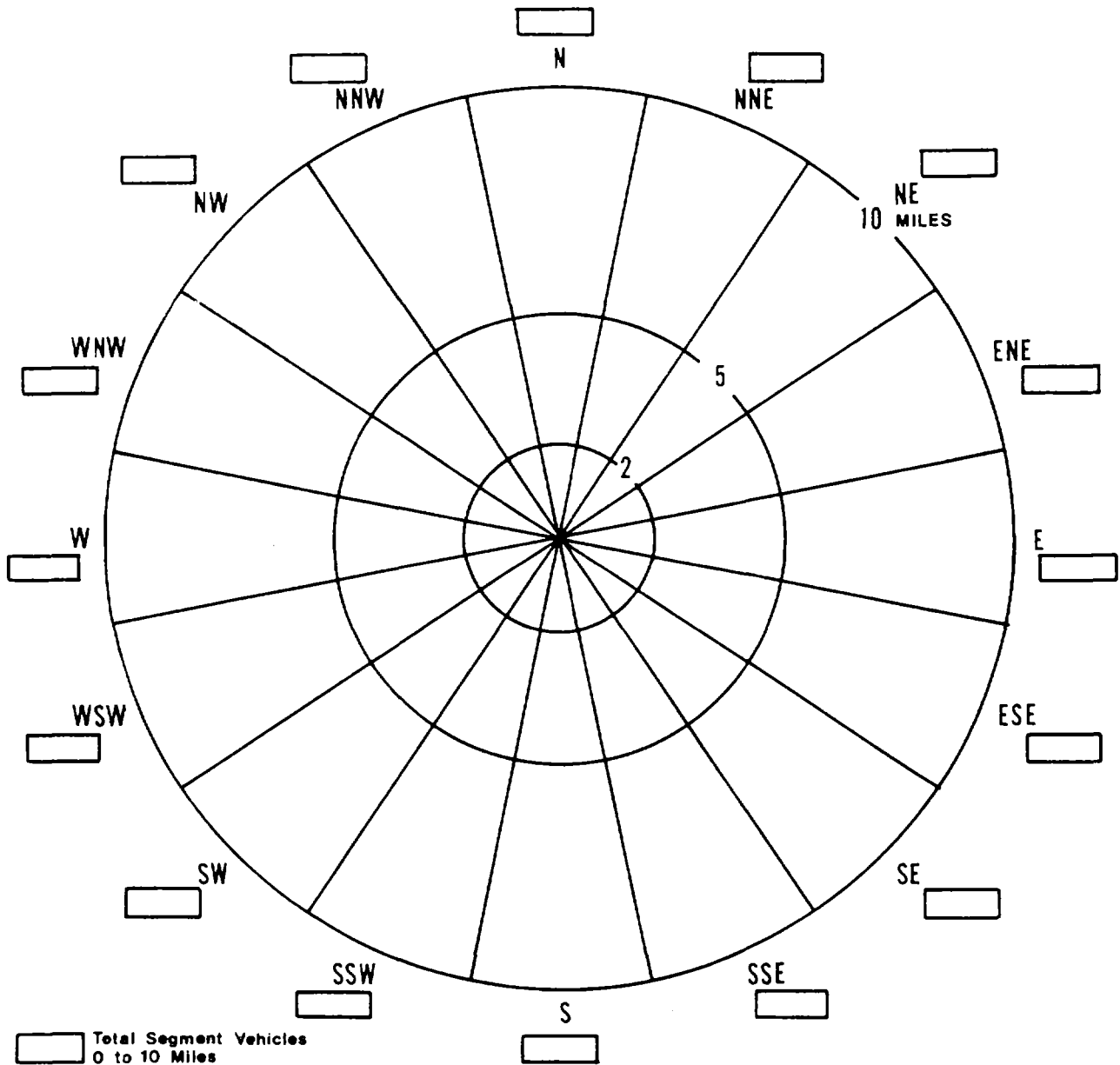
Figure 2: Example of Format for Presenting
Vehicle Data By Sector

A. Evacuation Roadway Network

A map showing only those roads used as primary evacuation routes would be shown. Figure 3 is an example. The map would not show local access streets necessary to get to the evacuation routes. Each segment of the network should be numbered in some manner for reference. The sector and quadrant boundaries should also be indicated.

B. Roadway Segment Characteristics

A table such as example Table 1 should be provided indicating all the evacuation route segments and their characteristics, including capacity, if known. The characteristics of a segment should be given for the narrowest section or bottleneck if the rqadway is not uniform in the number of lanes throughout the segment.

IV. ANALYSIS OF EVACUATION TIMES

As indicated previously, evacuation time is composed of several components. Each of these components must be estimated in order to determine the total evacuation time. Two types of evacuation should be considered in an evacuation analysis. One type is a partial evacuation involving one 90° sector. The other type is a total 360° evacuation. The 90° and 360° evacuations would be considered for 2 mile, 5 mile, and 10 mile evacuation distances.

Table 2 shows a possible format for presenting the data and results for each type of evacuation. Each of the evacuation time components is presented along with the total evacuation time. Two conditions--normal
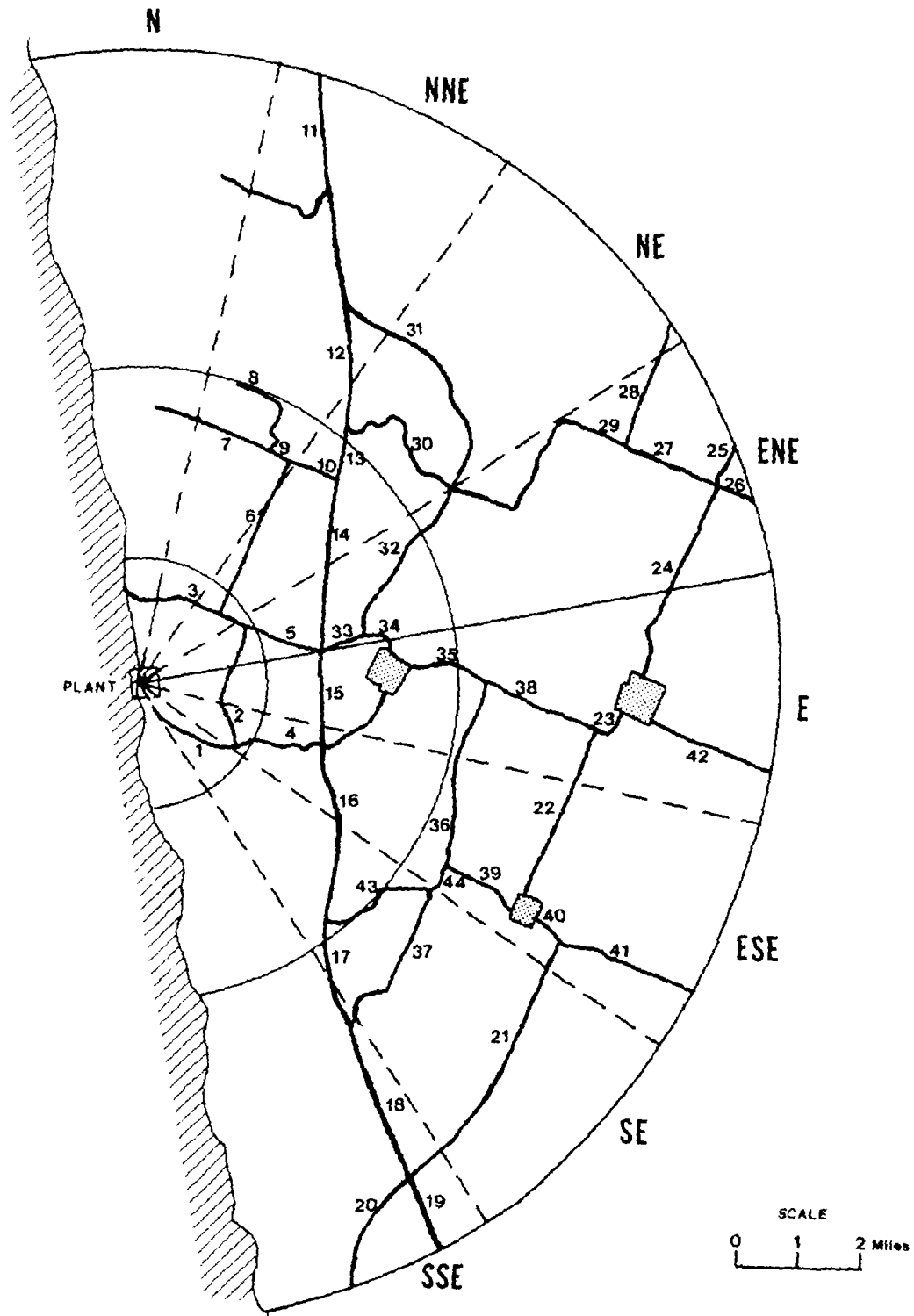
Figure 3:   Example of Evacuation Roadway Network

Table 1: Example of Roadway Characteristics

Segment	Number[1] of Lanes	Type[2]	Capacity[3]	Comments[4]

NOTES: [1]Total number of through lanes in both directions. If roadway cross section is not uniform, use section with least number of lanes

[2]F = Freeways and Expressways
U = Urban Streets
R = Rural Highways

[3]If known

[4]Indicate any special conditions that may affect roadway capacity.

Table 2: Example of Summary of Results of Evacuation Times Analysis

SECTORS	WITHIN TWO MILES				WITHIN FIVE MILES						WITHIN TEN MILES					
Permanent Population																
Permanent Pop. Vehicles																
Transient Population																
Transient Pop. Vehicles																
Evacuation Capacity Per Hour																
Notification Time																
Preparation Time																
Permanent Pop. Response Normal Conditions																
Permanent Pop. Response Adverse Contitions																
Transient Pop. Response Normal Conditions																
Transient Pop. Response Adverse Conditions																
General Pop. Evac. Time Normal Conditions																
General Pop. Evac. Time Adverse Conditions																
Confirmation Time																
Special Pop. Evac. Time Normal Conditions																
Special Pop. Evac. Time Adverse Conditions																

and adverse--are considered in the analysis. Adverse conditions would depend on the characteristics of a specific site and could include snow, fog or rain. As mentioned above, the sectors should be keyed to an accompanying map.

The text accompanying the table must clearly indicate the critical assumptions which underlie the time estimates; e.g., day versus night, workday versus weekend, peak transient versus off-peak transient, evacuation on adjacent sectors versus nonevacuation. The relative significance of alternative assumptions must be addressed, especially with regard to time dependent traffic loading of the segments of the evacuation roadway network.

Some modification of the format would be appropriate, depending on local circumstances. For example, notification time may be different for normal and adverse conditions.

The method for computing total evacuation time should be specified, since it is not necessarily the sum of all the time components. For example, if notification time is 45 minutes and response time is 60 minutes, it may be reasonable to assume that somes evacuees start moving after 15 minutes. However, if warning time is 60 minutes and response time is 15 minutes, it may not be reasonable to reduce the sum of warning and response time much, if any, below 75 minutes. It is also likely that special population response time is independent of response time for permanent residents and transients. Calculation of the total response time, therefore, requires the consideration of the appropriate evacuation time components and their interaction.

APPENDIX B

ANALYSIS TO BE PERFORMED ON SUBMITTALS

Two types of analyses will be performed on the evacuation times estimates submitted for the various nuclear power plant sites. First, the plans will be compared to the example format presented in Appendix A with an assessment made as to the quality and completeness of the analysis. The second area of analysis will be a comparison of the analyses and results among the various plants. The following will discuss both aspects in detail.

The areas covered in the example plan provided in Appendix A are summarized in Table 1. Each submittal will be evaluated against the listed criteria on a subjective ranked scale. If a criterion is not addressed, the rating given would be "none." If a criterion is addressed, but given inadequate consideration, a rating of "poor" would be assigned. Those submittals providing the minimum acceptable consideration of a criterion would be given an "adequate" rating. Finally, those analyses that are clearly of superior quality and completeness would receive an "excellent" rating.

The last aspect of the evaluation is an overall subjective rating of the evacuation time estimates taking into account the individual rating of the factors. A simple numerical summation of factors is not possible because the importance of the factors varies. The proposed analysis, while subjective in nature, does indicate in what areas the reviewer considers the plan to be strong or weak; therefore, it would provide a basis for resolving weaknesses.

Several variables have been identified for comparing and characterizing the set of the time estimates which have been submitted. First, however, some simple statistics such as minimum, average, and maximum total evacuation times would be computed. The same statistics would also be computed for the various evacuation time components. Table 2 is a suitable format for presenting the various statistics.

Three variables have been identified in this preliminary analysis for use in evaluating the estimates of evacuation time. The variables identified are population density, population type and traffic capacity.

Population density might be stratified into categories such as high, medium and low. The number of categories and the boundaries will require further analysis. Population type would include the three previously specified: permanent, transient and special. Traffic capacity is a variable proposed to measure the extent of transportation facilities in the area. The number and type of categories are tentative at this time. The controlling number of lanes exiting the critical quadrant will be evaluated as the proposed measure since roadway capacities are unlikely to be reported in most plans.

An analysis using a cross classification of two or more variables is proposed for the initial screening. By computing simple averages, central values, or ranges for various categories, it is possible to see if any potential relationships might exist. The technique, in addition to being simple, also precludes the need to assume a relationship which is necessary for techniques such as regression analysis. Table 3 illustrates a hypothetical cross classification table for population density and population type.

Table 1: Evacuation Criteria

Item	Excel.	Adeq.	Poor	None

Background
 	
  A. Area Map
  B. Assumptions
  C. Methodology
 	
Demand Estimation
 	
  A. Permanent Population
  B. Transient Population
  C. Special Population
  D. Time of Day/Week
 	
Traffic Routing
 	
  A. Map of Network
  B. Capacity by Segment
 	
Analysis
 	
  A. Components Considered
  B. Adverse Condition
       Considered
 	
Overall				

Table 2: Evacuation Time Statistics

Evacuation Time

Component	Minimum	Average	Maximum
Total			
Notification			
Preparation			
Response			
Confirmation			

For each site, the report containing these analyses will contain an appendix which combines the suggested output of Appendix A (to the extent available) with the evaluation proposed in Table 1.

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16. ABSTRACT *(200 words or less)*

In the analysis, limitations of current methodologies and some alternatives are discussed that point out that evacuation time is a combination of the time required for four separate actions. These are decision, notification, preparation, and response (travel) time. Times for these actions will overlap to some degree with some people receiving notification, some preparing to leave and others traveling. Notification and preparation times significantly affect the evacuation time and must be known before time to clear an area can be calculated accurately.

Notification, preparation, and response times must be explicitly considered to identify critical relationships between the three. Estimates for segments of a 10-mile zone should have two evacuation times - one for evacuation of that segment and a second one for simultaneous evacuation of the segment and contiguous segments of the zone.

Adverse weather, day versus night, and special facilities (concentrations of workers or patients) require separate consideration.

The paper concludes with a sample study and an analysis to be performed on evacuation studies.

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